Table 4.8.1. Major Chemical and Radiological Ground-Water Contaminants and Their Link to Site Operations

Facilities Type	Area	Constituents Generated
Reactor operations	100	Tritium, ^{60}Co, ^{90}Sr, ^{125}Sb, Cr^{+6}, SO_4^{-2}
Irradiated fuel processing	200	Tritium, ^{90}Sr, ^{99}Tc, ^{129}I, ^{137}Cs, Pu, U, CN^-, Cr^{+6}, F^-, NO_3^-
Plutonium purification	200	Pu, ^{241}Am, carbon tetrachloride, chloroform, NO_3^-
Fuel fabrication	300	^{99}Tc, U, Cr^{+6}, Cu, trichloroethylene

and produces ground-water contaminant plumes. The presence of non-aqueous phase liquid has a major impact on the Site's ground-water remediation strategy because the organic liquid in the subsurface represents a continuing source of ground-water contamination but is very difficult to clean up. Ground-water contamination in the 300 Area was mainly from discharge of wastes from fuel fabrication. Historically, the discharge water during Site operations had a major impact on ground-water flow beneath Hanford and thus affected the rate and direction of contamination spread. The effects of discharge have been dissipating since production operations ceased.

Liquid effluents discharged to the ground at Hanford facilities percolated downward through the unsaturated zone toward the water table. Radionuclide and chemical constituents moved through the soil column at varying rates, and in some cases, entered the ground water. In some locations, sufficient water was discharged to saturate the soil column to the surface.

Not all contaminants move at the same rate as the water in the subsurface. Chemical processes such as adsorption onto soil particles, chemical precipitation, and ion exchange slow the movement of some constituents such as cesium-137, plutonium-239,240, and strontium-90. Other radionuclides such as iodine-129, technetium-99, and tritium, and ions such as nitrate are not as readily retained by the soil and move vertically through the soil column at a rate nearly equal to the infiltrating water. When the liquid effluents reach the water table, their concentrations are reduced by dilution. As these constituents move with the ground water, radionuclide and chemical concentrations are reduced further by adsorption and spreading (dispersion), and radionuclide concentrations are reduced by radioactive decay.

Outside the source areas at the Hanford Site there is typically little or no downward gradient so contamination tends to remain just below the water table. Flow in the unconfined aquifer is toward the Columbia River. Contamination that reaches the river is further diluted by the river water.

Ground-Water Monitoring

Ground-water monitoring at the Hanford Site is an integral part of the *Hanford Site Ground-Water Protection Management Plan* (DOE 1995d). The plan integrates monitoring at active waste disposal facilities to comply with the Resource Conservation and Recovery Act, operational monitoring in and adjacent to reactor and chemical processing facilities, and environmental surveillance. Monitoring is also carried out during cleanup investigations under the Comprehensive Environmental Response, Compensation, and Liability Act programs (DOE 1992d). The Resource Conservation and Recovery Act and operational monitoring programs are managed by the Site operating contractor. The Comprehensive Environmental Response, Compensation, and Liability Act investigations are managed by the Environmental Restoration Contractor. Additional details on Resource Conservation and Recovery Act-compliant monitoring are presented in Section 2.0, "Environmental Compliance Summary."

The Hanford Ground-Water Surveillance Project has been designed to assess the distribution and movement of existing ground-water contamination and to identify potential and emerging ground-water contamination problems. The project integrates information on contaminant distribution and transport into a sitewide evaluation of ground-water quality.

Collection and Analysis of Ground-Water Samples

Ground-water samples were collected as part of the Hanford Ground-Water Surveillance Project and other monitoring programs. The Hanford Ground-Water Surveillance Project uses data from other programs to provide a more complete interpretation. Monitoring data from past years supplement the current analyses and allow for the evaluation of trends through time. Wells monitored by the various programs are shown in Figures 4.8.9 and 4.8.10. These figures indicate only well names that are specifically discussed in the text. Due to the high concentration of unconfined aquifer wells in the operational areas, only 600-Area unconfined aquifer wells are shown. Other unconfined aquifer wells called-out in the text are shown on detailed maps for those areas in the following sections. Ground-water monitoring was conducted at the facilities shown in Figure 4.8.11 to comply with the Resource Conservation and Recovery Act (Hartman 1996).

Ground-water samples were collected from approximately 800 wells for all monitoring programs during 1995. The Ground-Water Surveillance Project sampled 499 wells. The monitoring frequency for the wells was selected based on regulatory requirements, proximity to waste sources, and characteristics of the ground-water flow system at the sample location. Of the wells sampled, approximately 270 were sampled once, 280 were sampled twice, 100 were sampled three times, 90 were sampled four times and 60 were sampled more frequently during the year. Wells at the Hanford Site generally follow a naming system in which the well name indicates the approximate location of the well. The prefix of the well name indicates the area of the Site, as shown in Table 4.8.2. The well names for 600-Area wells follow a local coordinate system in which the numbers indicate the distance relative to an arbitrary datum location in the south-central part of the Site.

Each monitoring program has access to ground-water data collected by other programs through a common database used to store and manage data. This database, called the Hanford Environmental Information System, currently contains approximately 1.4 million ground-water monitoring result records. After the data are verified and/or validated, they are made available to federal and state regulators for retrieval.

Most ground-water monitoring wells on the Site are 10 to 20 cm (4 to 8 in.) in diameter. Monitoring wells for the unconfined aquifer are constructed with well screens or perforated casing generally in the upper 3 to 6 m (10 to 20 ft) of the unconfined aquifer, with the open interval extending across the water table. This construction allows sample collection at the top of the aquifer, where maximum concentrations of radionuclides tend to be found. Wells monitoring the shallowest of the basalt confined aquifers have screens, perforated casing, or an open hole within the monitored aquifer. Wells drilled before 1985 were generally constructed with carbon steel casing. Wells recently constructed for Resource Conservation and Recovery Act monitoring projects and Comprehensive Environmental Response, Compensation, and Liability Act characterizations have been constructed with stainless-steel casing and screens. Most monitoring wells onsite are sampled using either submersible or Hydrostar pumps although some wells are sampled with bailers or air-lift systems.

Samples were collected for all programs following documented sampling procedures (PNL 1993, WHC 1991b) based on EPA guidelines (EPA 1986a). Analytical techniques used are listed in Dresel et al. (1995), the *Environmental Monitoring Plan* (DOE 1994a), and Comprehensive Environmental Response, Compensation, and Liability Act work plans. The radionuclides and chemicals analyzed are listed in Table 4.8.3. Several of the parameters listed in Table 4.8.3 were not measured during 1995 because sufficient characterization has been obtained by past analyses.

Most ground-water samples collected onsite in 1995 were analyzed for tritium. Selected samples were analyzed for other radionuclides. Sample results for radionuclides are generally presented in picocuries per liter. However, the results for total uranium, which is usually measured by laser fluorescence, are given in micrograms per liter. The results for analysis of individual uranium isotopes are reported in picocuries per liter.

Nitrate analyses were performed on many samples collected during 1995 because of the extensive areas with elevated nitrate concentrations originating from onsite and offsite sources. However, the elevated nitrate concentrations were below the Drinking Water Standard for most of the affected area. Selected monitoring wells were used for additional chemical surveillance. Chemical sampling wells were chosen by considering the results of
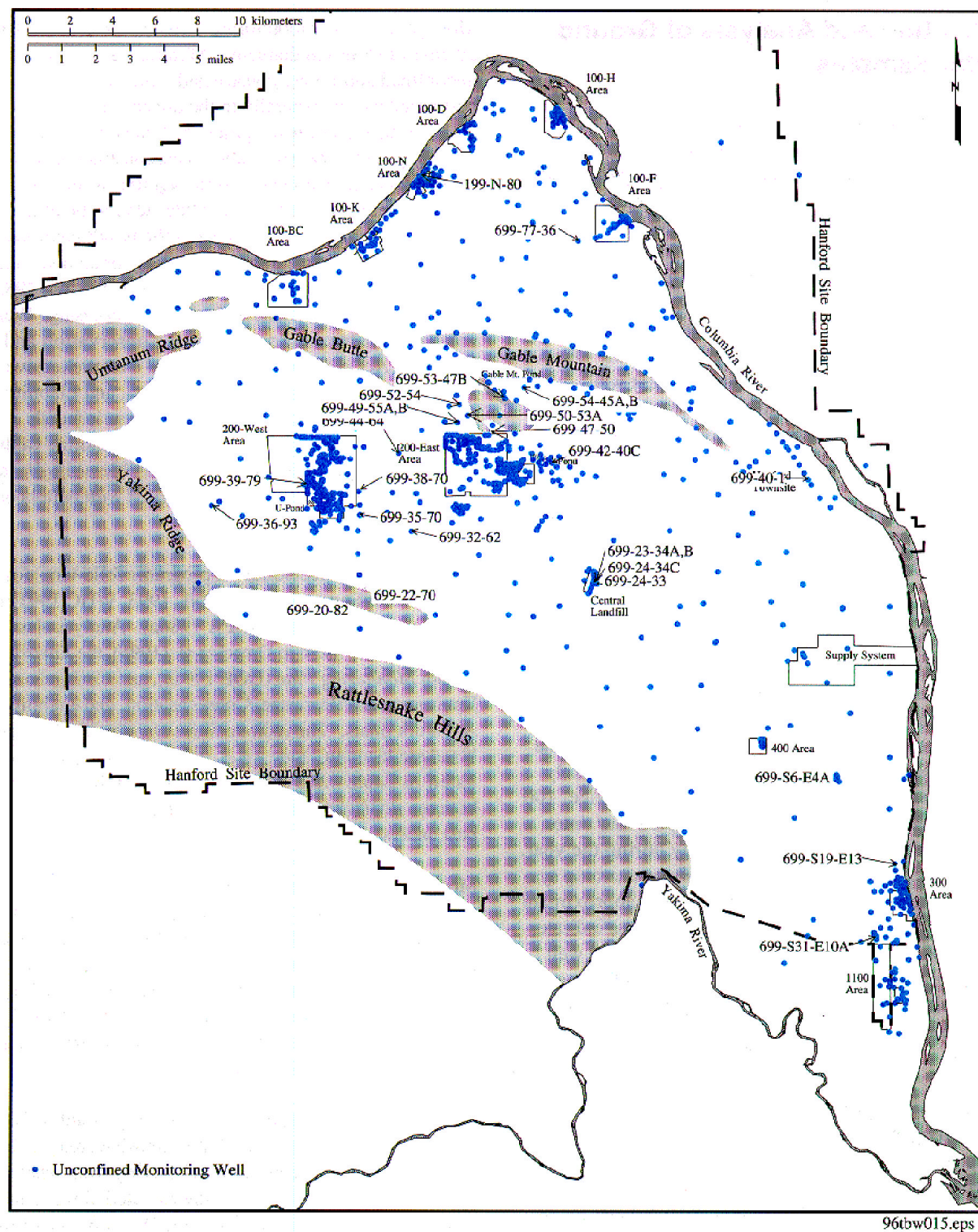
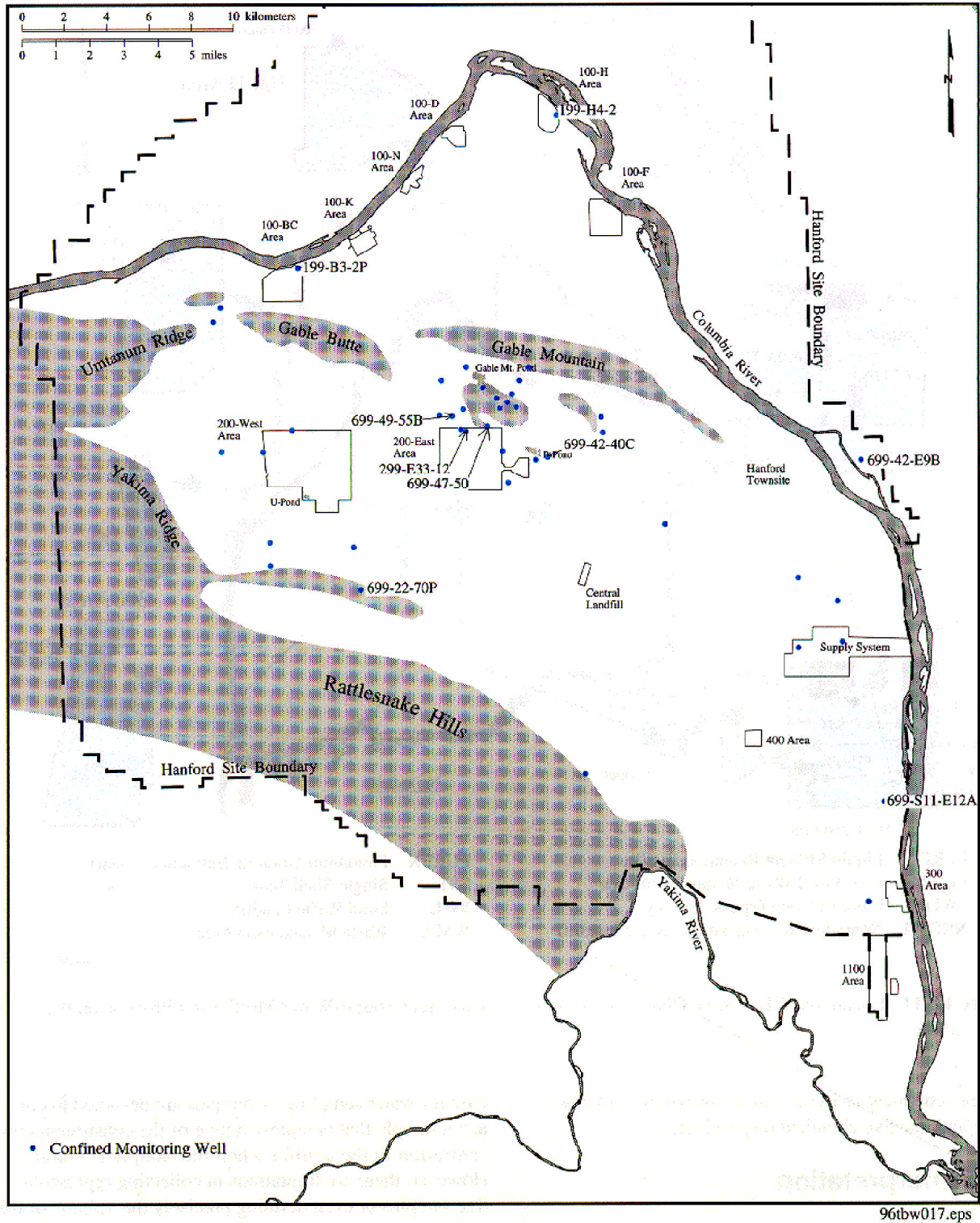**Figure 4.8.9**. Hanford Site Unconfined Aquifer Monitoring Well Locations, 1995
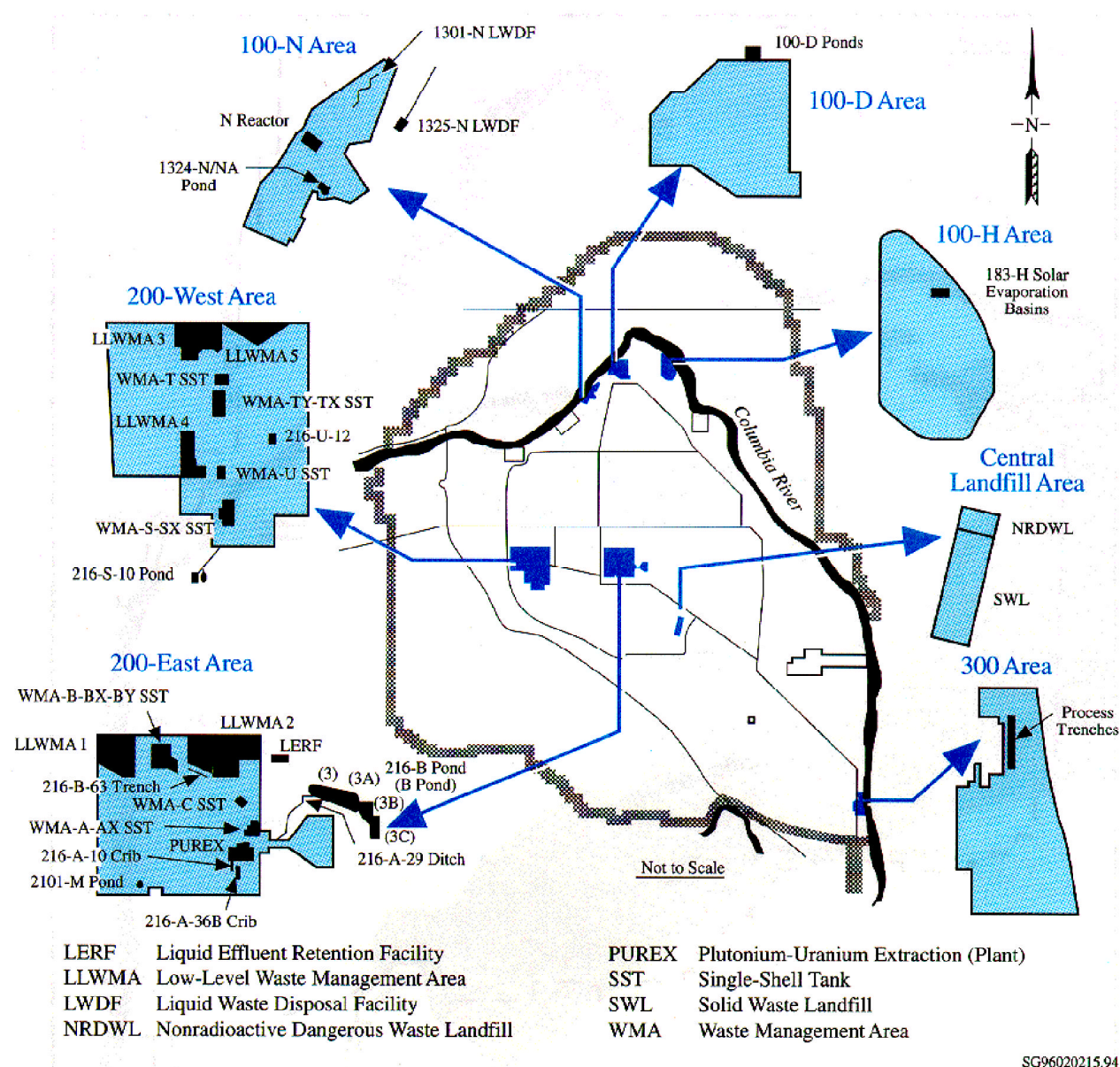
Figure 4.8.10. Hanford Site Confined Aquifer Monitoring Well Locations, 1995

Figure 4.8.11. Locations of Resource Conservation and Recovery Act Ground-Water Monitoring Projects on the Hanford Site

previous chemical analyses and the proximity to known active and inactive chemical disposal sites.

Data Interpretation

Each analysis of a ground-water sample provides information on the composition of ground water at one time at one location in the aquifer. Uncertainty in the analyses results from a number of sources. Some of the sources of uncertainty are discussed below. Several techniques used to interpret the sample results are also discussed.

Ground-water sampling techniques are designed to collect a sample that is representative of the constituent concentration in the aquifer when the sample is taken. However, there are limitations in collecting representative samples or even defining precisely the volume of the aquifer represented by the sample. Proper well construction and maintenance, well purging, sample preservation, and, in some instances, filtering are used to help ensure consistent and representative samples. Careful sample labeling protocols, chain-of-custody documentation, and bottle preparation avoid many gross errors in sample

Table 4.8.2. Explanation of the Hanford Site Well Naming System

Example Well Name	Area
199-	**100 Area**
199-B3-47	100-BC Area
199-D5-12	100-D Area
199-F8-3	100-F Area
199-H4-3	100-H Area
199-K-30	100-K Area
199-N-67	100-N Area
299-	**200 Area**
299-W19-3	200-West Area
299-E28-4	200-East Area
399-	**300 Area**
399-1-17A	300 Area
499-	**400 Area**
499-S1-8J	400 Area
699-	**600 Area**
699-50-53A	600 Area north and west of datum
699-42-E9A	600 Area north and east of datum
699-S19-11	600 Area south and west of datum
699-S19-E13	600 Area south and east of datum

Note: Letters at end of well names distinguish either multiple wells located close together or multiple intervals within a single well-bore.

results. Duplicate samples and field blanks are used to assess the sampling procedure.

Uncertainties are inherent in laboratory analysis of samples. Gross errors can be introduced in the laboratory or during sampling. Gross errors include transcription errors, calculation errors, mislabeling results, or other errors that result from not following established procedures. Often, these gross errors can be recognized because unreasonably high or unreasonably low values result. Data review protocols are used to investigate and correct gross errors. Even if the source of a possible gross

error cannot be identified, a marker is entered into the database indicating the review has occurred and the datum may be suspect.

Random errors are unavoidably introduced in the analytical procedures. Usually there are insufficient replicate analyses to assess the overall random error at each sample location. Instruments for analysis of radioactive constituents count the number of radioactive decay products at a detector, and background counts are subtracted. The nature of radioactive decay and the instrument design result in a random counting error, which is reported with the analytical result. Generally, sample results less than the counting error indicate the constituent was not detected. The background subtraction may result in the reporting of results that are less than zero. Although below-zero results are physically impossible, the negative values are of use for some statistical analyses (see Helpful Information Section for more details).

Systematic errors may result from instrument calibration, standard or sample preparation, chemical interferences in analytical techniques, as well as sampling methodology and sample handling. Sample and laboratory protocols have been designed to minimize systematic errors. The laboratories used by the Ground-Water Surveillance Project and other programs participate in interlaboratory comparisons in which many laboratories analyze blind samples prepared by the EPA (see Section 7.0, "Quality Assurance").

In 1995, double-blind samples for specific constituents were analyzed as part of the Ground-Water Surveillance Project (see Section 7.0, "Quality Assurance," for further discussion of double-blind results). Several wells were also co-sampled with the Washington State Department of Health for intercomparison. Results of the intercomparison sampling are available from the Washington State Department of Health.

The chemical composition of ground water may fluctuate from differences in the contaminant source, recharge, or the ground-water flow-field. The range of this concentration fluctuation can be estimated by taking many samples, but there is a limit to the number that can be practically taken. Comparison of results through time helps interpret this variability.

Overall sample uncertainty may be factored into data evaluation by considering the concentration trend in a given well over time. This often helps identify gross

Table 4.8.3. Radionuclides and Chemicals Analyzed for in Ground Water

Radiological Parameters	Chemical Parameters
^{3}H	pH (field and laboratory)
^{14}C	Conductance (field)
^{60}Co	Alkalinity
^{90}Sr	Total carbon
^{99}Tc	Total organic carbon
^{103}Ru	Total organic halogens
^{106}Ru	B, Be, Na, Mg, Al, K, Co, Si
^{125}Sb	Ca, V, Cr, Mn, Fe, Ni
^{129}I	Cu, Zn, Sr, Ag, Cd, Sb, Ba
^{131}I	F^-, Cl^-, NO_3^-, PO_4^{-3}, SO_4^{-2}, NO_2^-, Br^-
^{137}Cs	CN^-
^{241}Am	NH_4^+
Total alpha	Volatile organic compounds (VOCs)
Total beta	Semivolatile organic constituents
Plutonium isotopes	Polychlorinated biphenyls
Uranium isotopes	Dioxins/furans
Uranium (total)	Pesticides/herbicides
	Biological oxygen demand/chemical oxygen demand
	Dissolved oxygen

errors, and overall long-term trends can be distinguished from short-term variability. The interpretation of concentration trends depends on an understanding of chemical properties as well as site hydrogeology. The trend analysis in turn aids in refining the conceptual model of the chemical transport.

Plume maps presented in this section are diagrams that illustrate Site ground-water chemistry. Although analytical data are available only at specific points where wells were sampled, contours are drawn to join the approximate locations of equal chemical concentration or radionuclide activity. The contour maps are simplified representations of plume geometry because of map scale, the lack of detailed information, and the fact that plume depth and thickness cannot be fully represented on a two-dimensional map. Plume maps are a powerful tool because knowledge

of concentrations in surrounding wells, ground-water flow, site geology, and other available information are factored into map preparation.

Ground-Water Monitoring Results

The following sections of the report summarize the most significant results of ground-water monitoring for the year. Further information on the interpretations are presented in the Ground-Water Surveillance Project's annual report (Dresel et al. 1995). The ground-water report also includes ground-water analytical results for the year in electronic format.

One way to assess the impact of radionuclides and chemicals in ground water is to compare the concentrations to EPA's Drinking Water Standards and DOE's Derived Concentration Guides (Appendix C, Tables C.2 and C.5). Specific Drinking Water Standards have been proposed for only a few radiological constituents. Drinking Water Standards resulting in an annual dose of 4 mrem/yr have been calculated for other radionuclides by considering the half-life of the isotope, the energy and nature of the radioactive decay for that isotope, and physiological factors such as the buildup of the isotope in particular organs. Drinking Water Standards are more restrictive than the DOE Derived Concentration Guides because the Drinking Water Standards are based on an annual dose to the affected organ of 4 mrem/yr, and the DOE Derived Concentration Guides for drinking water are based on an effective dose equivalent of 100 mrem/yr (see Appendix C, Tables C.2 and C.5). In addition, the EPA Drinking Water Standards use older factors for calculating the concentrations that would produce a 4 mrem/yr dose than are used in calculating DOE Derived Concentration Guides. Thus, the values used below for Drinking Water Standards are not always in agreement with the DOE Derived Concentration Guides. The DOE Derived Concentration Guides are available only for radionuclides. Primary and secondary Drinking Water Standards are given for some chemical constituents. Secondary Drinking Water Standards are based on aesthetic rather than health considerations.

Radiological Monitoring Results for the Unconfined Aquifer

Radionuclides analyzed in ground water are listed in Table 4.8.3. Iodine-131, ruthenium-103, and ruthenium-106 have relatively short half-lives and historically have been detected near operating reactors or liquid waste disposal facilities near active fuel reprocessing facilities. These radionuclides have not been observed in concentrations above the Drinking Water Standards, and in general, have not been detected since soon after the shutdown of N Reactor and the Plutonium-Uranium Extraction Plant. The detection limit for ruthenium-106 by gamma scan is higher than the Drinking Water Standard, but with a half-life of only 1 year, ruthenium-106 decays rapidly to concentrations less than the Drinking Water Standard. Gross (total) alpha and beta are used as indicators of radionuclide distribution and are not discussed in detail because the specific radionuclides contributing to these measurements are discussed. The distribution of tritium, iodine-129, strontium-90,

technetium-99, uranium, cobalt-60, cesium-137, plutonium, and antimony-125 will be discussed in the following sections. The locations and types of operations resulting in the release of these radionuclides to ground water are listed in Table 4.8.1.
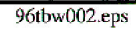
Tritium

Tritium was present in many waste streams discharged to the subsurface and is the most mobile radionuclide onsite. As a result, the extent of contamination in the ground water from Site operations is generally reflected by the tritium distribution. Tritium is the radionuclide most frequently monitored at the Hanford Site for this reason. Significant quantities of tritium are associated with irradiation of nuclear fuel. The source of the tritium is generally believed to be low-yield ternary fission (rare events, in which the nucleus decays into three atomic fragments) although irradiation of lithium impurities in the fuel could also be responsible. Tritium is released through decladding and dissolution of the fuel. Process condensates associated with the elevated temperature portions of the fuel processing cycle provide a release pathway for that tritium. Tritium was also manufactured as part of the Site mission. Tritium was produced by irradiating lithium-containing targets in the 100-H and 100-B reactors from 1949 to 1952 (Gerber 1993). In the late 1960s, tritium production took place in the 100-N reactor (Gerber 1992). Figure 4.8.12 shows the 1995 distribution of tritium in the unconfined aquifer.

Tritium in the 100 Areas. Tritium concentrations greater than the 20,000-pCi/L Drinking Water Standard were detected in the 100-B, 100-D, 100-F, 100-K, and 100-N Areas. One sample from the 100-B Area, from well 199-B5-2, contained 27,000 pCi/L of tritium, slightly above the Drinking Water Standard. Although this well appears to show an increasing trend in tritium concentration, wells upgradient show lower tritium levels. Tritium concentrations greater than the Drinking Water Standard were detected in two wells in the 100-D Area. The maximum tritium level reported was 44,000 pCi/L in monitoring well 199-D5-12.

Only one well in the 100-F Area (199-F8-3) contained tritium at concentrations greater than the Drinking Water Standard (a maximum of 111,000 pCi/L). This well is located near the 118-F-1 Burial Ground. The source and downgradient extent of this contamination has not been determined.

Figure 4.8.12. Distribution of Tritium in the Unconfined Aquifer, 1995

Well 199-K-30, located in the 100-K Area, continued to contain the highest tritium concentration within the 100 Areas, with a maximum concentration of 1,560,000 pCi/L reported in 1995. Previously, in April and May 1993, this well contained tritium in excess of the DOE Derived Concentration Guide (2,000,000 pCi/L). The tritium trend for well 199-K-30 is shown in Figure 4.8.13. The source of tritium contamination found in well 199-K-30 is subject to some question. Although the contamination has been attributed to leakage of the K-East reactor fuel storage basin, another potential source is past disposal to a French drain east of the reactor building (DOE 1993a). A careful evaluation of the contaminant trends and distribution of other constituents such as antimony-125, carbon-14, and strontium-90 suggests that the primary source of tritium is not leakage of the fuel storage basin. However, basin leakage has possibly contributed to contamination found in well 199-K-27, located just north of the K-East reactor building. Tritium concentrations in monitoring well 199-K-27 continue to decline but remained well above the drinking water standard (maximum of 234,000 pCi/L) in 1995. Well 199-K-106A was installed in 1994 adjacent to a French drain near the K-West reactor building. Samples from this well revealed another high concentration tritium plume. The maximum concentration of tritium detected in well 199-K-106A in 1995 was 711,000 pCi/L.

Tritium in the 100-N Area is found in concentrations greater than the Drinking Water Standard in the northern part of the area, extending to the surrounding 600 Area. This plume is associated with two liquid waste disposal trenches, 1301-N Liquid Waste Disposal Facility and 1325-N Liquid Waste Disposal Facility. The maximum tritium level reported in the 100-N Area in 1995 was 70,200 pCi/L in well 199-N-75, located between the 1301-N Liquid Waste Disposal Facility and the Columbia River. This value is comparable to results ranging from 58,600 to 72,000 pCi/L from 1992 through 1994.

Tritium in the 200 Areas. The highest tritium concentrations in the 200-East Area continued to be in wells near cribs that received effluent from the Plutonium-Uranium Extraction Plant. Concentrations greater than the 2,000,000-pCi/L DOE Derived Concentration Guide were detected in only one well in 1995 in the 200-East Area, 299-E17-9. The tritium level detected in this well monitoring the 216-A-36B Crib was 3,470,000 pCi/L, which was the highest concentration detected in any well onsite. The tritium concentration in this well is generally declining slowly, as shown in Figure 4.8.14. Concentrations in monitoring wells downgradient of the 216-A-10 Crib decreased to less than the DOE Derived Concentration Guide in 1993 and remained below the DOE Derived Concentration Guide in 1995. Although
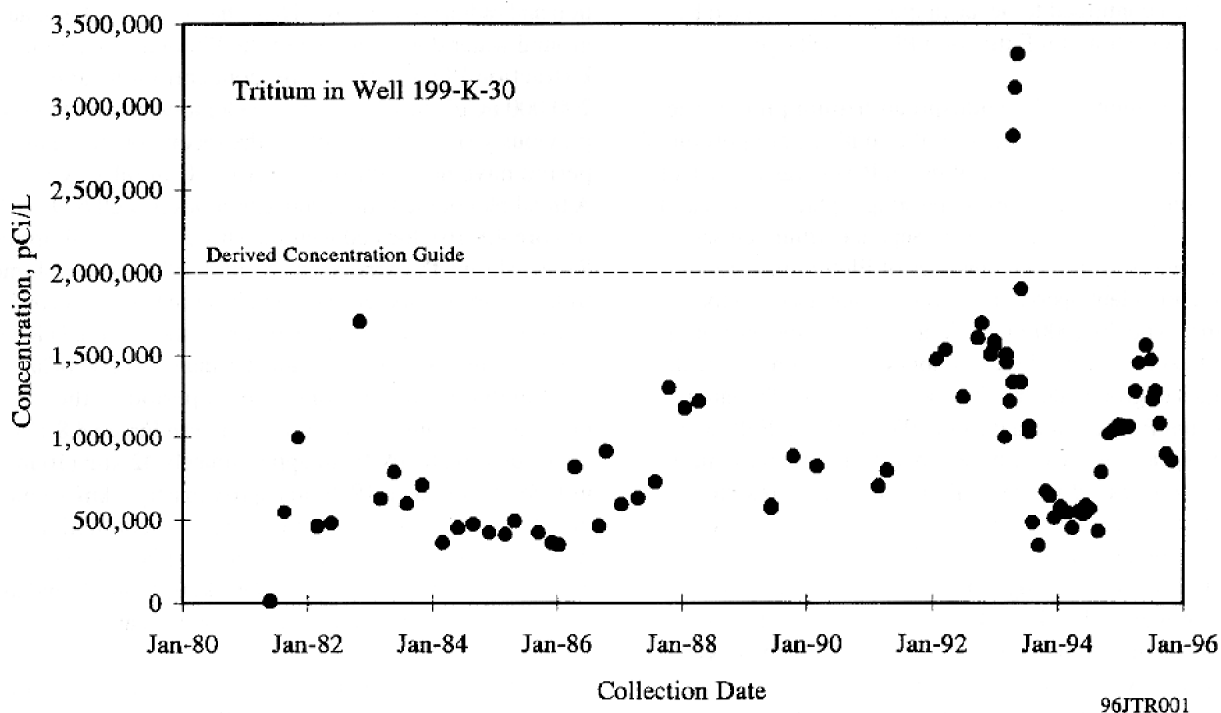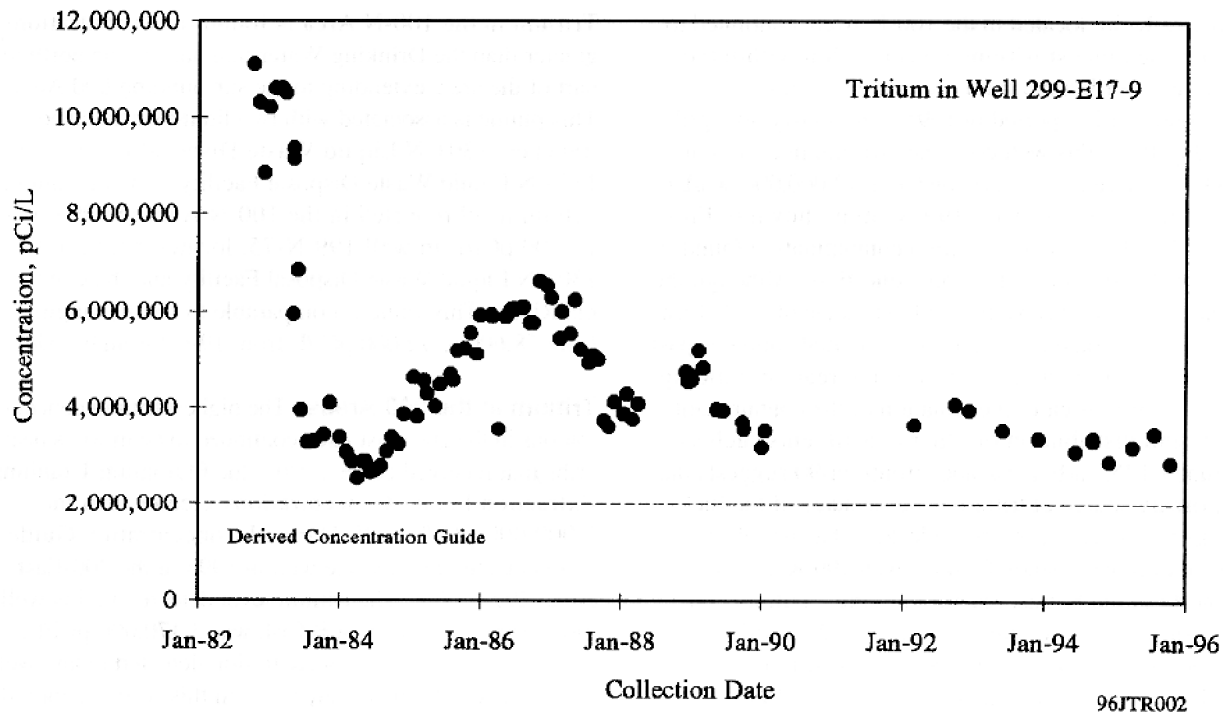

Figure 4.8.13. Tritium Concentrations in Well 199-K-30, 1981 Through 1995

Figure 4.8.14. Tritium Concentrations in Well 299-E17-9, 1982 Through 1995

tritium concentrations are generally decreasing in wells near the Plutonium-Uranium Extraction Plant cribs, tritium concentrations exceeding the Drinking Water Standard continued to occur in many wells affected by Plutonium-Uranium Extraction Plant discharge.

The movement of the widespread tritium plume (see Figure 4.8.12) extending from the southeastern portion of the 200-East Area to the Columbia River was consistent with patterns noted in past monitoring reports (Dirkes and Hanf 1995, Dresel et al. 1995). Separate tritium pulses associated with the two episodes of Plutonium-Uranium Extraction Plant operations can be distinguished in the plume. The 200,000-pCi/L lobe of the plume east of the 200-East Area near the Columbia River is a result of discharges to ground during the operation of the Plutonium-Uranium Extraction Plant from 1956 to 1972. Following an 11-year shutdown, plant operation began again in 1983 and ceased in December 1988. This resulted in elevated tritium concentrations measured in several wells downgradient from the 200-East Area. Movement of the leading edge of this plume is clearly observable in well 699-24-33, Figure 4.8.15, which shows arrival of the plume in early 1987 following the passage of the plume from the earlier operation of the Plutonium-Uranium Extraction Plant. Tritium concentrations from

the first plume were much higher than from the second. Concentrations of tritium detected in 1995 in this plume were generally lower than in previous years due to dissipation and radioactive decay. Thus, the area of contaminated ground water downgradient of the Plutonium-Uranium Extraction Plant with tritium concentrations above 200,000 pCi/L in 1995 was considerably smaller than in previous years. The effects of the second operational period have not been seen near the Columbia River. A trend plot of the tritium concentrations in well 699-40-1 (Figure 4.8.16), located near the shore of the Columbia River, shows the arrival in the mid-1970s of the plume from the first campaign and no indication that the second pulse has yet arrived. The area near the Columbia River with tritium concentrations greater than 200,000 pCi/L, attributable to the first operational period of the Plutonium-Uranium Extraction Plant (see Figure 4.8.12), continues to shrink from approximately 42 km² (16 mi²) in 1988 (Evans et al. 1989) to approximately 7 km² (3 mi²) in 1995. However, the overall extent of contamination from the Plutonium-Uranium Extraction Plant at levels greater than the 20,000 pCi/L Drinking Water Standard remained nearly the same as in previous years.

The tritium plume resulting from Site activities has been monitored for much of the time the Site has been in